US006146121A

# United States Patent [19]

Fox et al.

[11] Patent Number: 6,146,121

[45] Date of Patent: Nov. 14, 2000

[54] **ROTOR FOR USE IN A ROTARY PUMP**

[75] Inventors: **Robert Fox**, Henley-on-Thames; **Morgan Heikal**, Brighton, both of United Kingdom

[73] Assignee: **APV UK Limited**, Berkshire, United Kingdom

[21] Appl. No.: **09/022,710**

[22] Filed: **Feb. 12, 1998**

[30] **Foreign Application Priority Data**

Feb. 12, 1997 [GB] United Kingdom .................. 9702836

[51] **Int. Cl.**[7] .................................................. **F01C 1/18**

[52] **U.S. Cl.** .................................. **418/206.1**; 418/206.5

[58] **Field of Search** .............................. 418/206.5, 206.1

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*Primary Examiner*—Thomas Denion
*Assistant Examiner*—Thai-Ba Trieu
*Attorney, Agent, or Firm*—Kenyon & Kenyon

[57] **ABSTRACT**

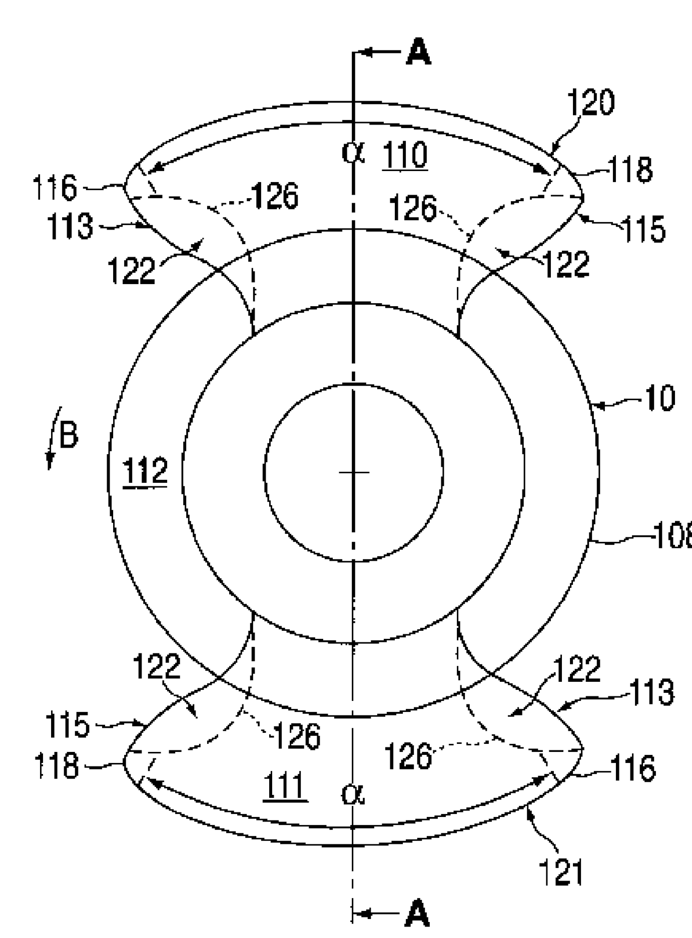
Fluid being pumped by rotary piston/lobe pumps is prone to fluid cavitation particularly at the leading and trailing edges of the rotor.

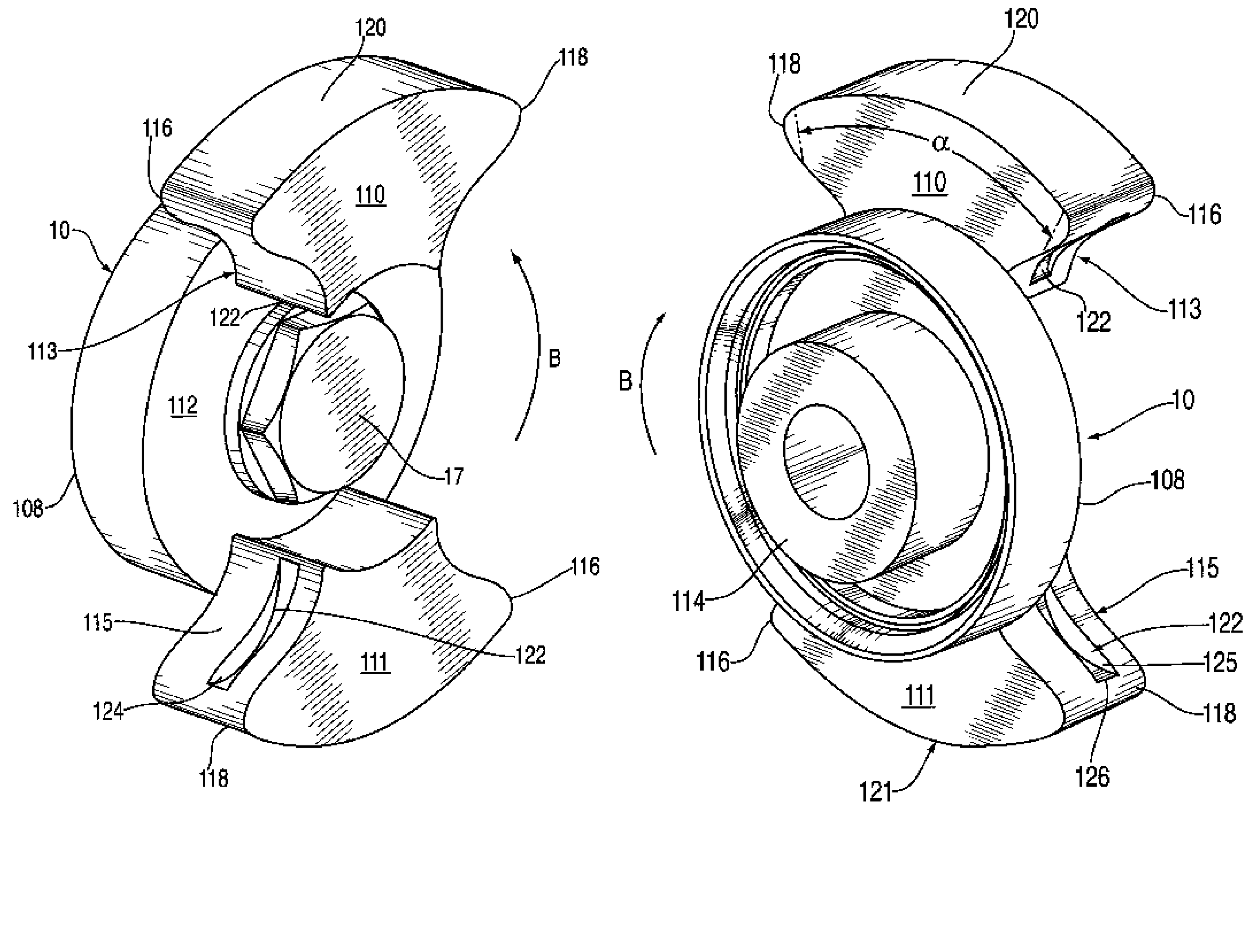
A rotor **10** comprises a generally cylindrical rotor hub portion **108** formed with two piston wing portions **110**, **111**. The piston wing portions **110**, **111** are disposed transversely of the axis **13** on a substantially flat surface **112** of the hub portion **108**. Extending from the surface **112** coaxially with axis **13**, and disposed radially within the rotor hub portion **108**, is a tubular portion **114** through which the end of shaft **15** passes when the rotary pump assembly is in an assembled state.

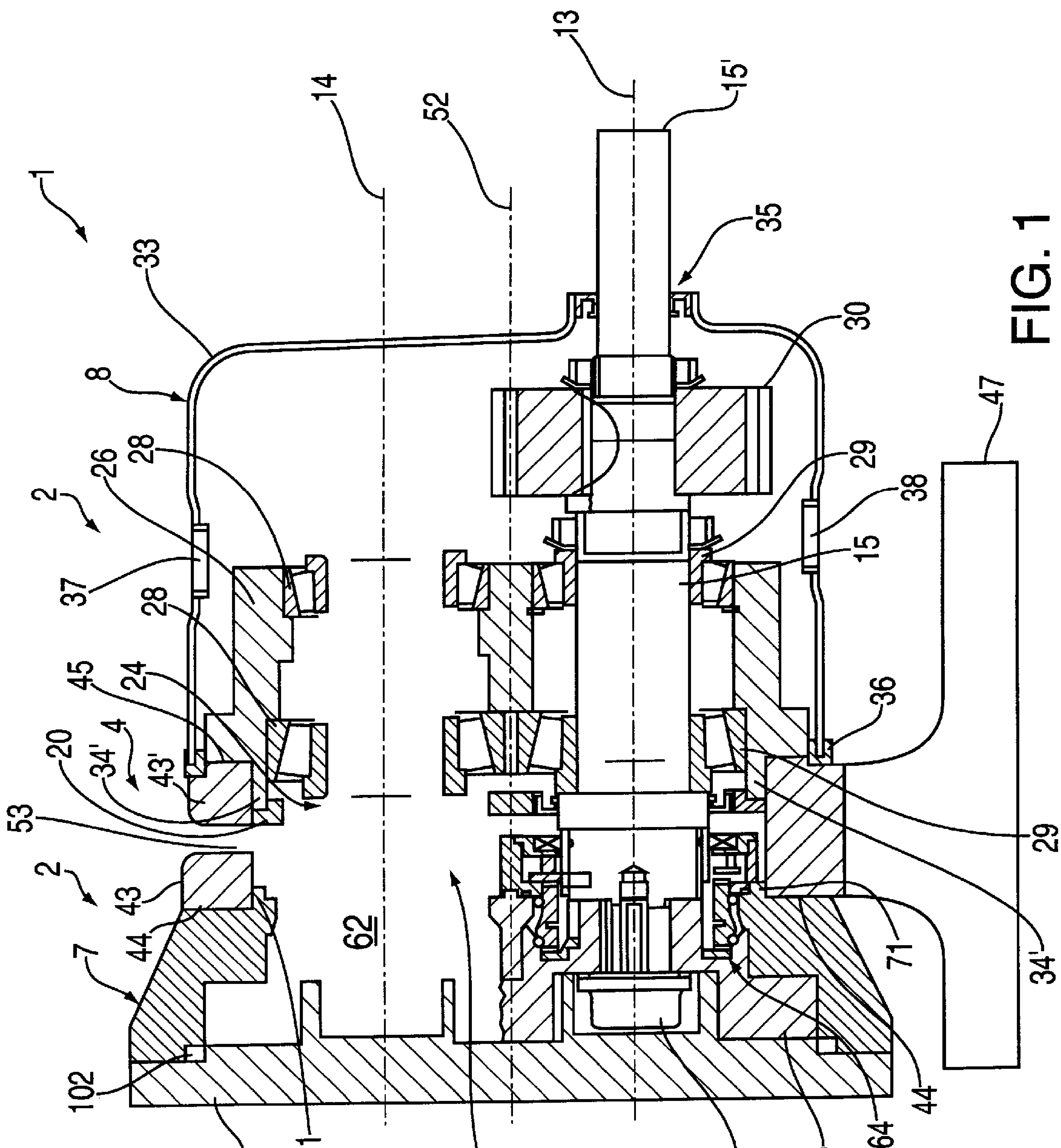
Each piston wing portion **110**, **111** is formed with a sinuous curved leading face region **113** and a sinuous curved trailing face region **115**.

The radially outermost (relative to the rotor axis) region of the leading face region **113** is formed with a leading curved edge part **116** and the radially outermost region of the trailing face region is formed with a trailing curved edge part **118**.

**24 Claims, 11 Drawing Sheets**

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15'
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33
34'
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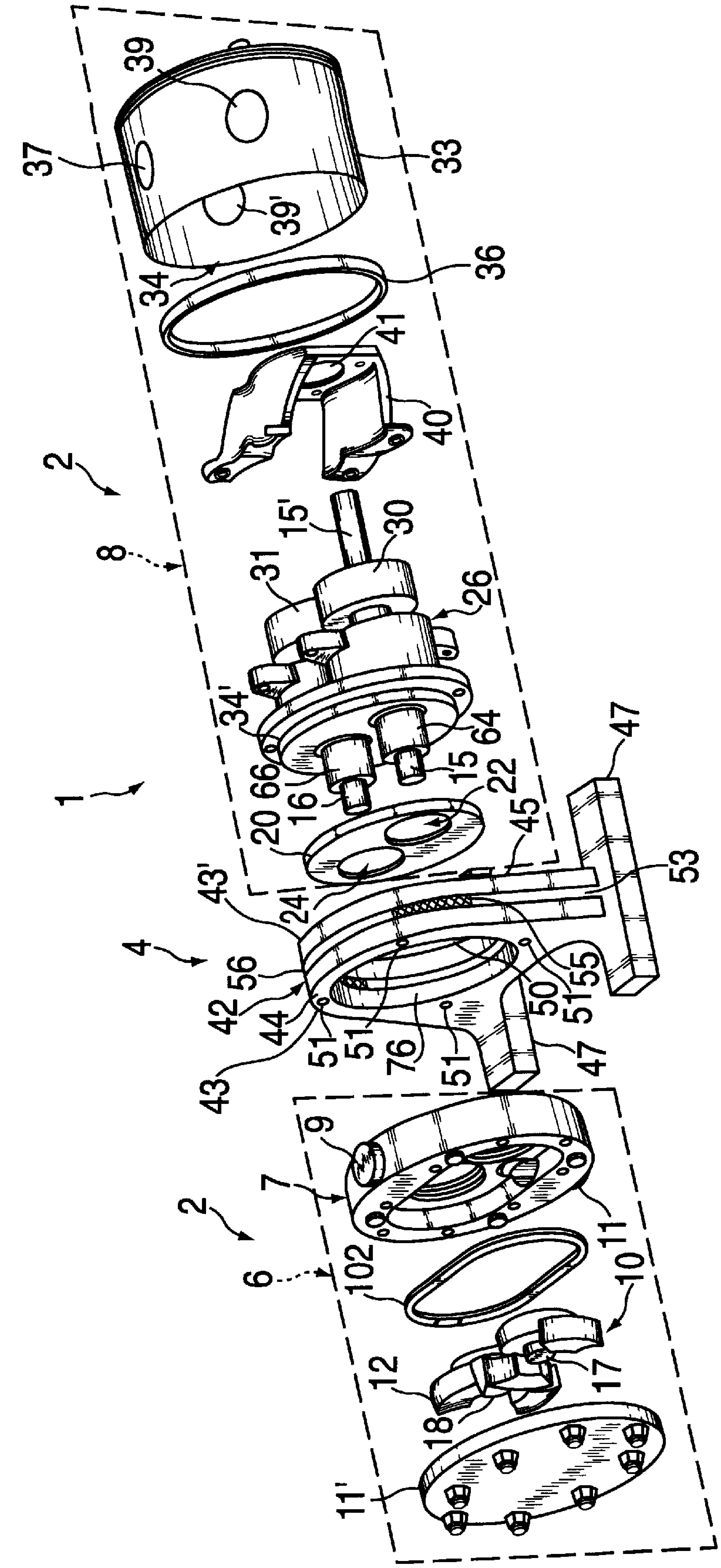
43
43'
44
45
47
50
52
53
62
64
71
102

FIG. 1



39
37
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39'
34
36
41
40
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15'
30
8
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64
66
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16
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43'
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55
42
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76
43
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9
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102
10
6
17
12
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FIG. 2

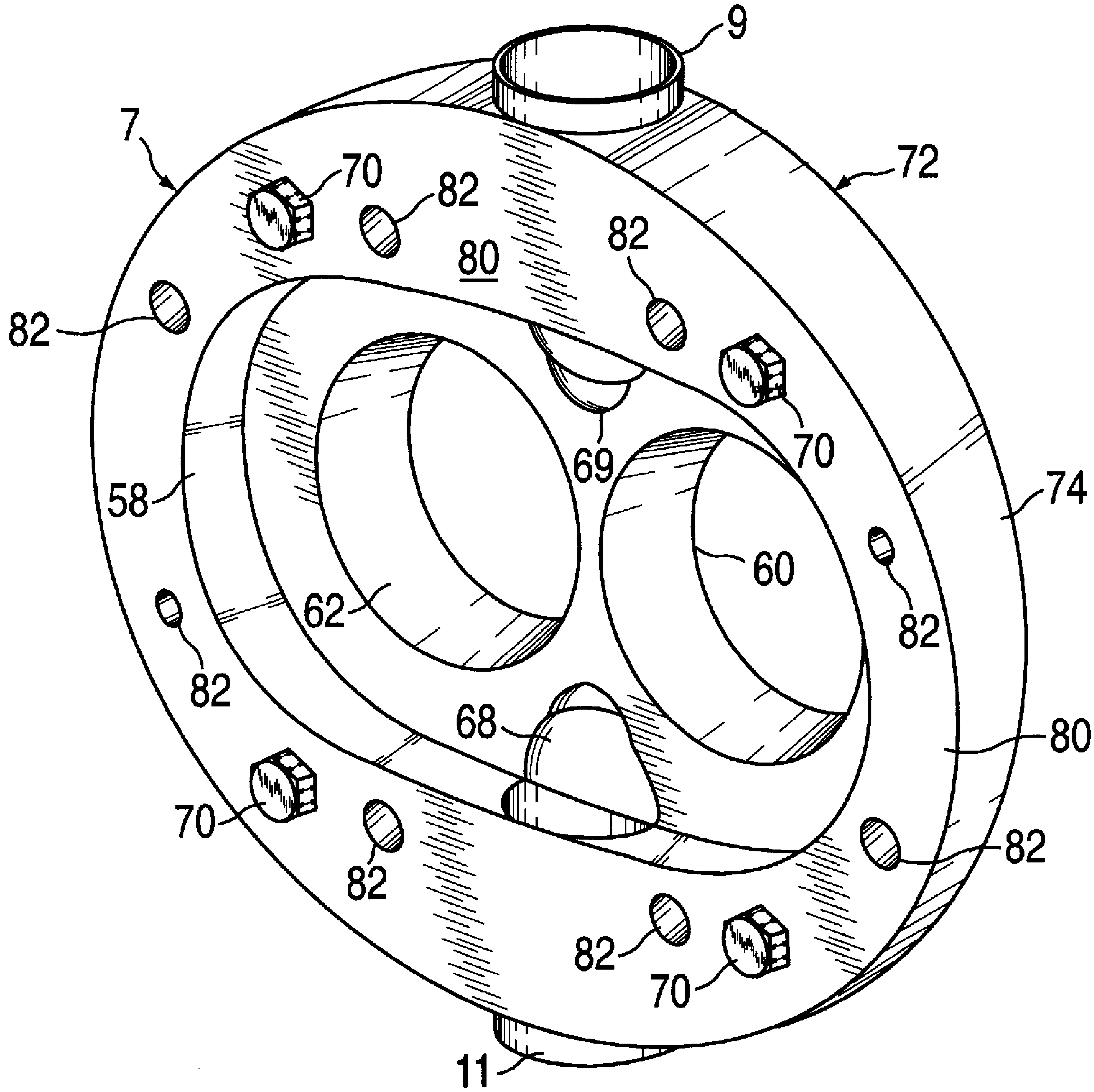



FIG. 3

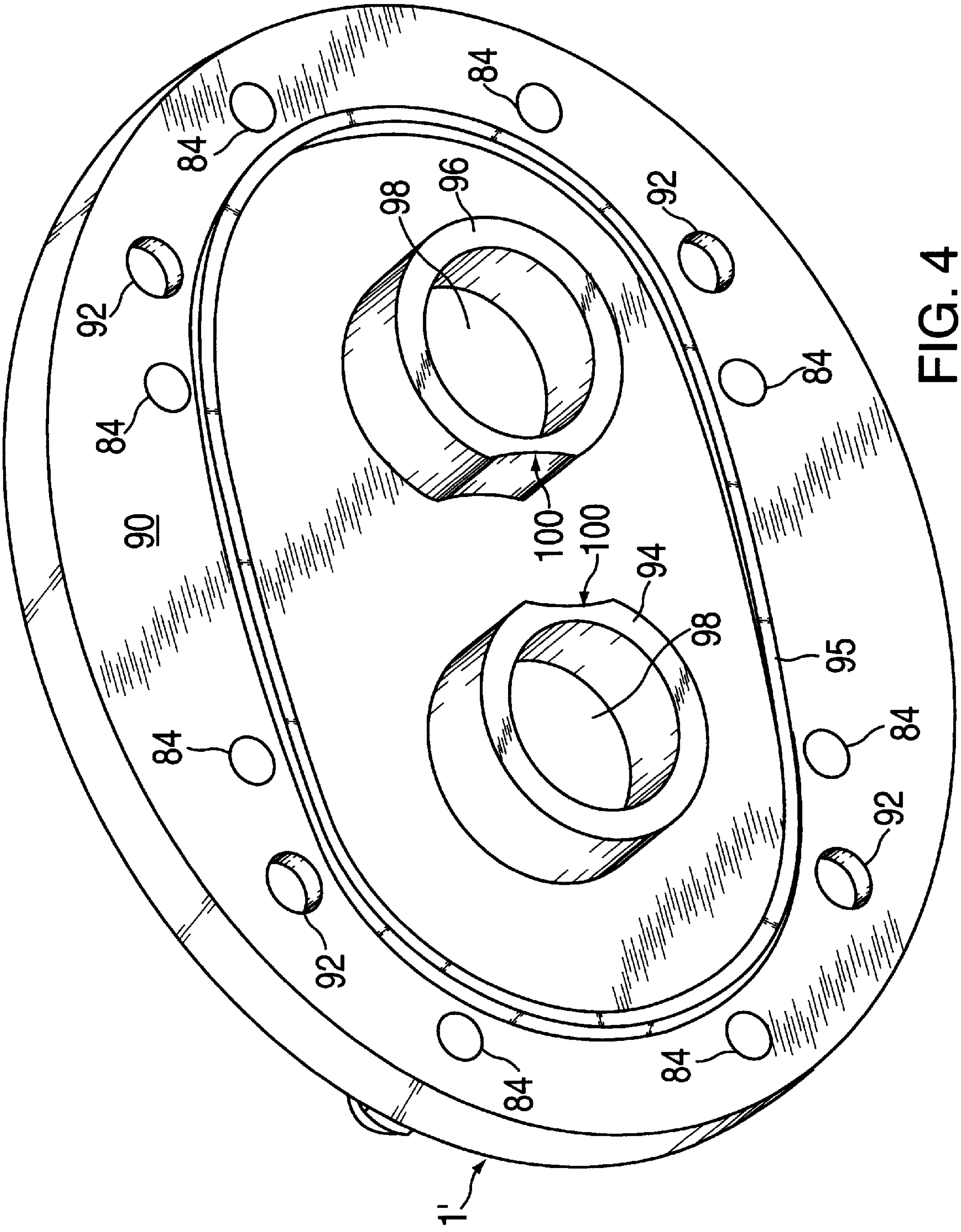
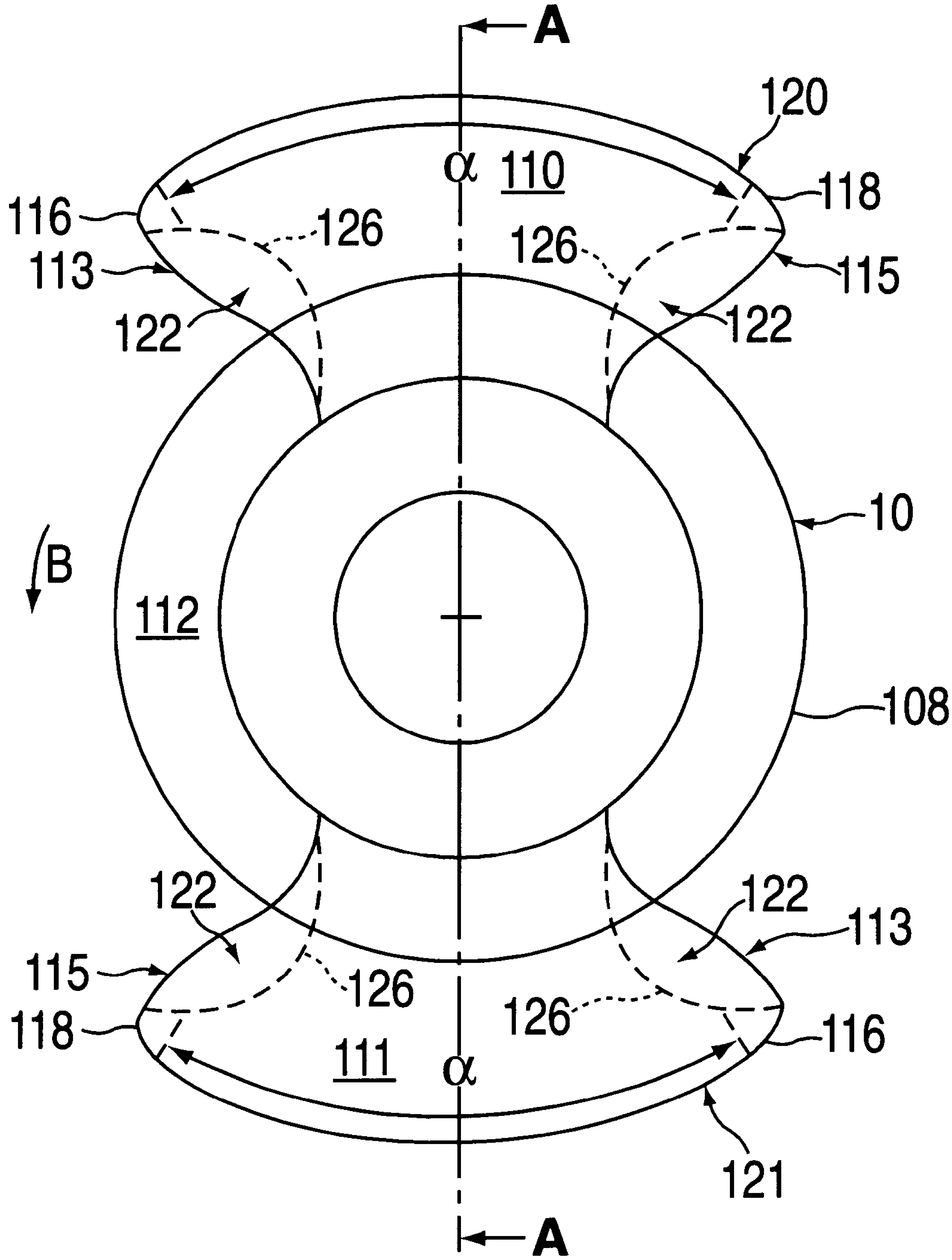



FIG. 4


A
120
α
110
116
118
126
126
113
115
122
122
10
B
112
108
122
122
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115
126
126
118
116
111
α
121
A

FIG. 5

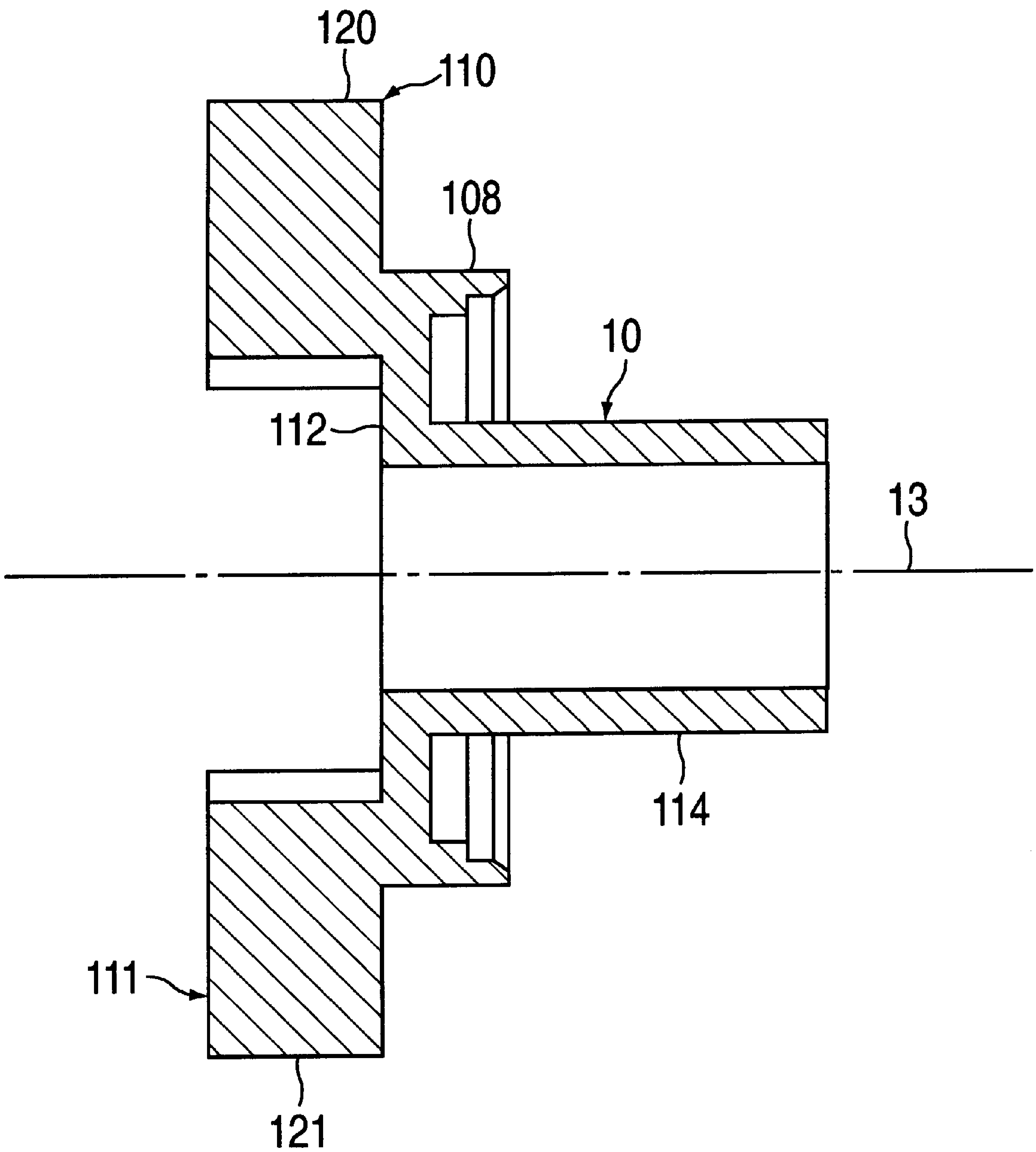



FIG. 6

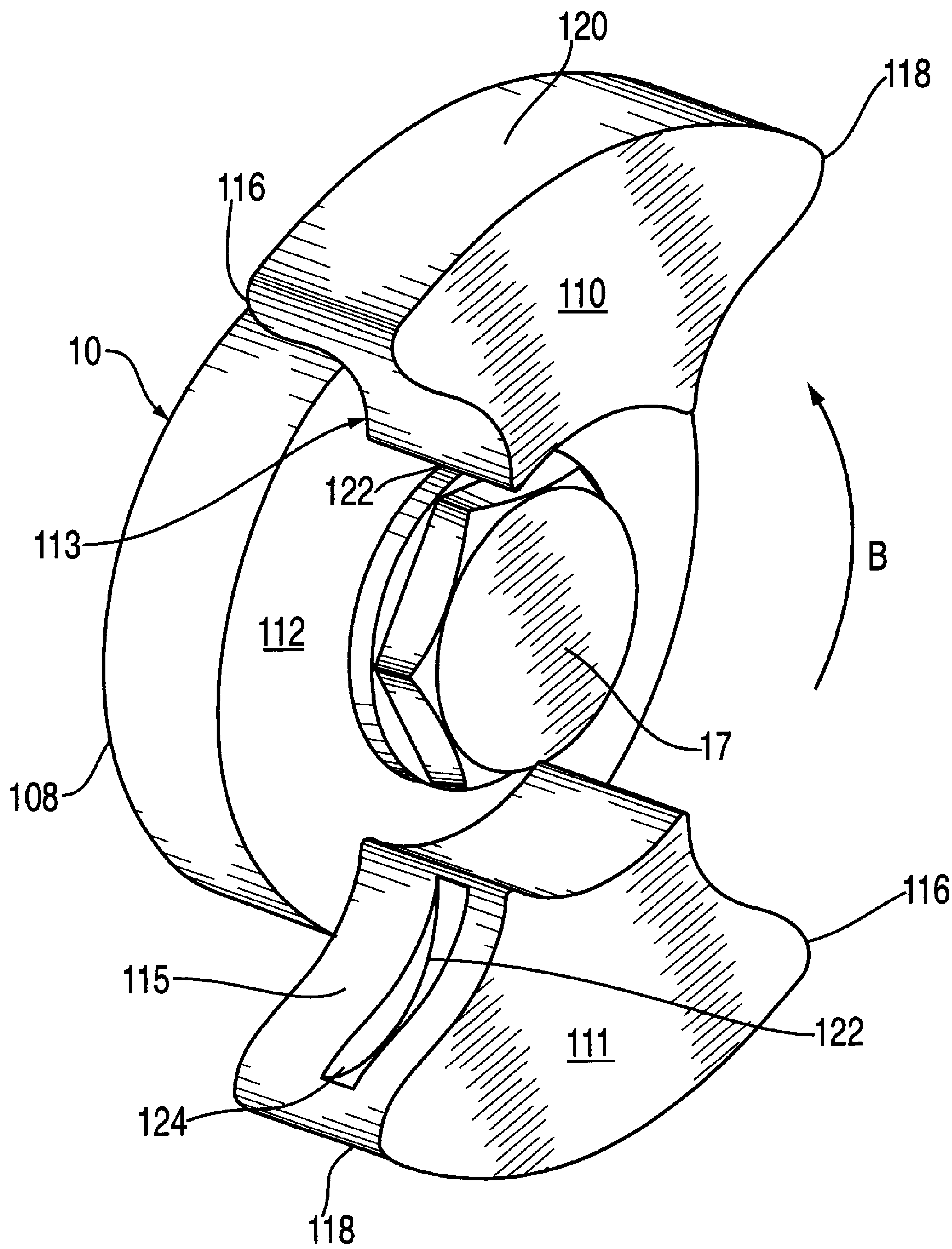
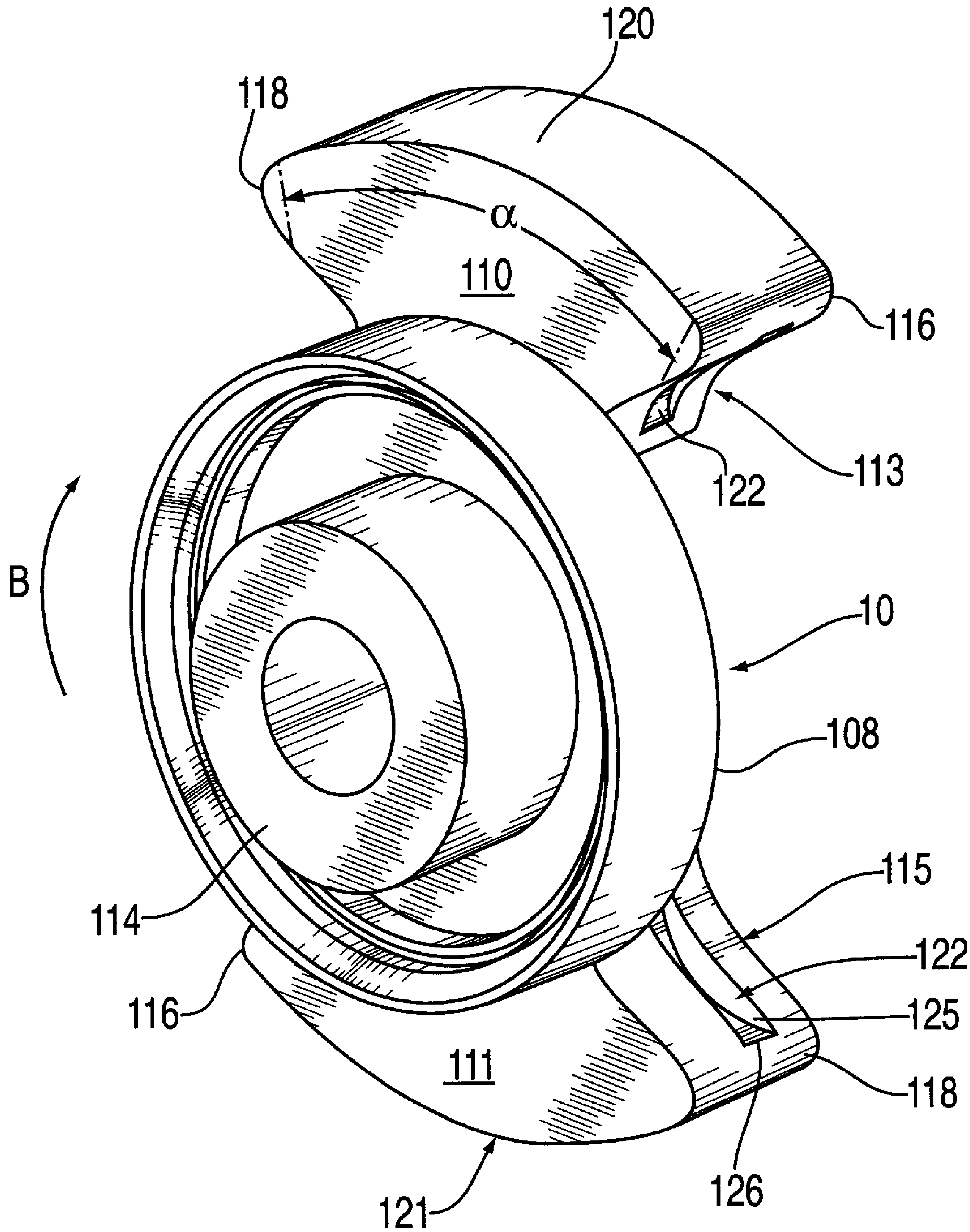



FIG. 7


120
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α
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125
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116
111
118
126
121

FIG. 8

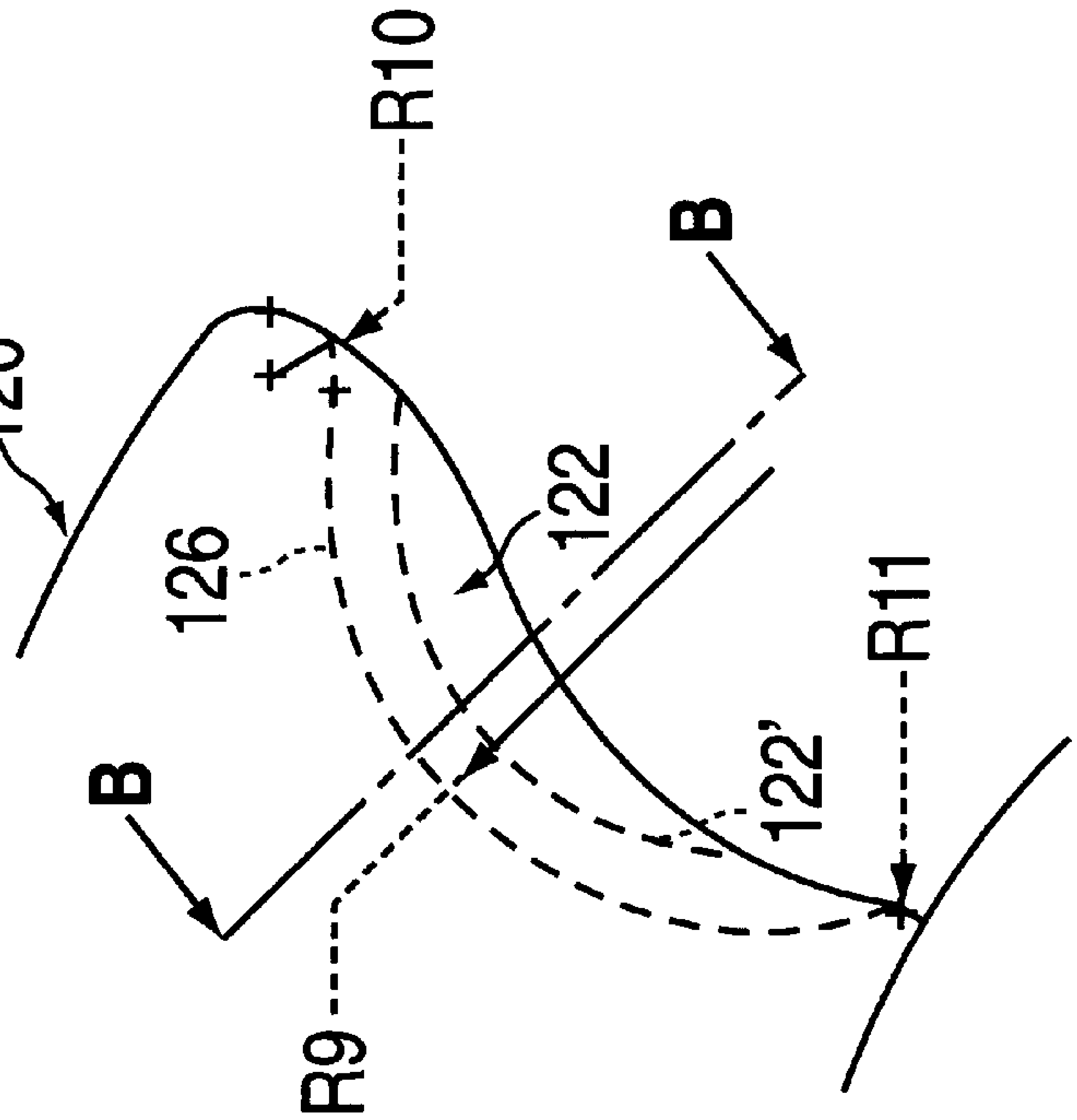



FIG. 10

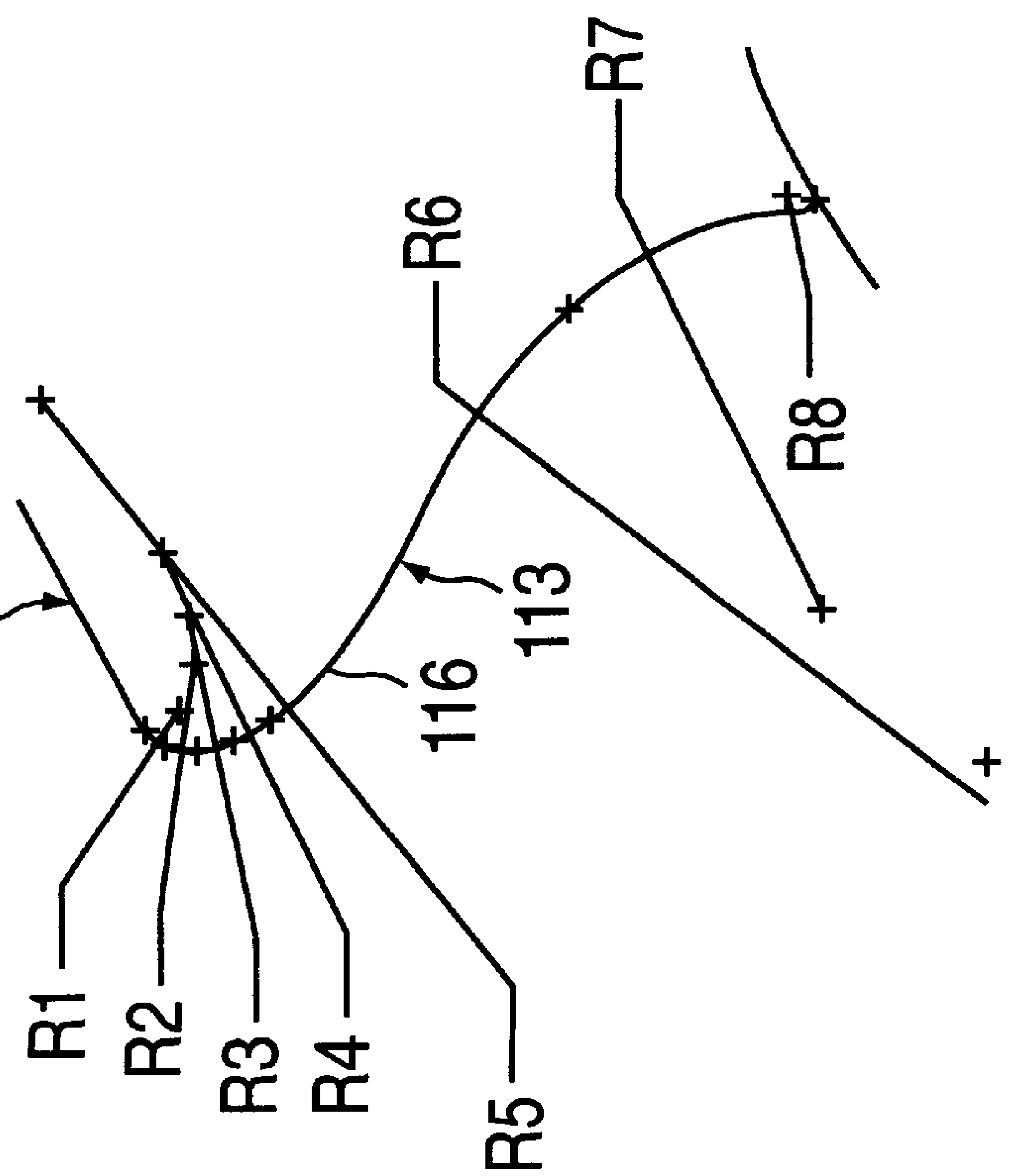
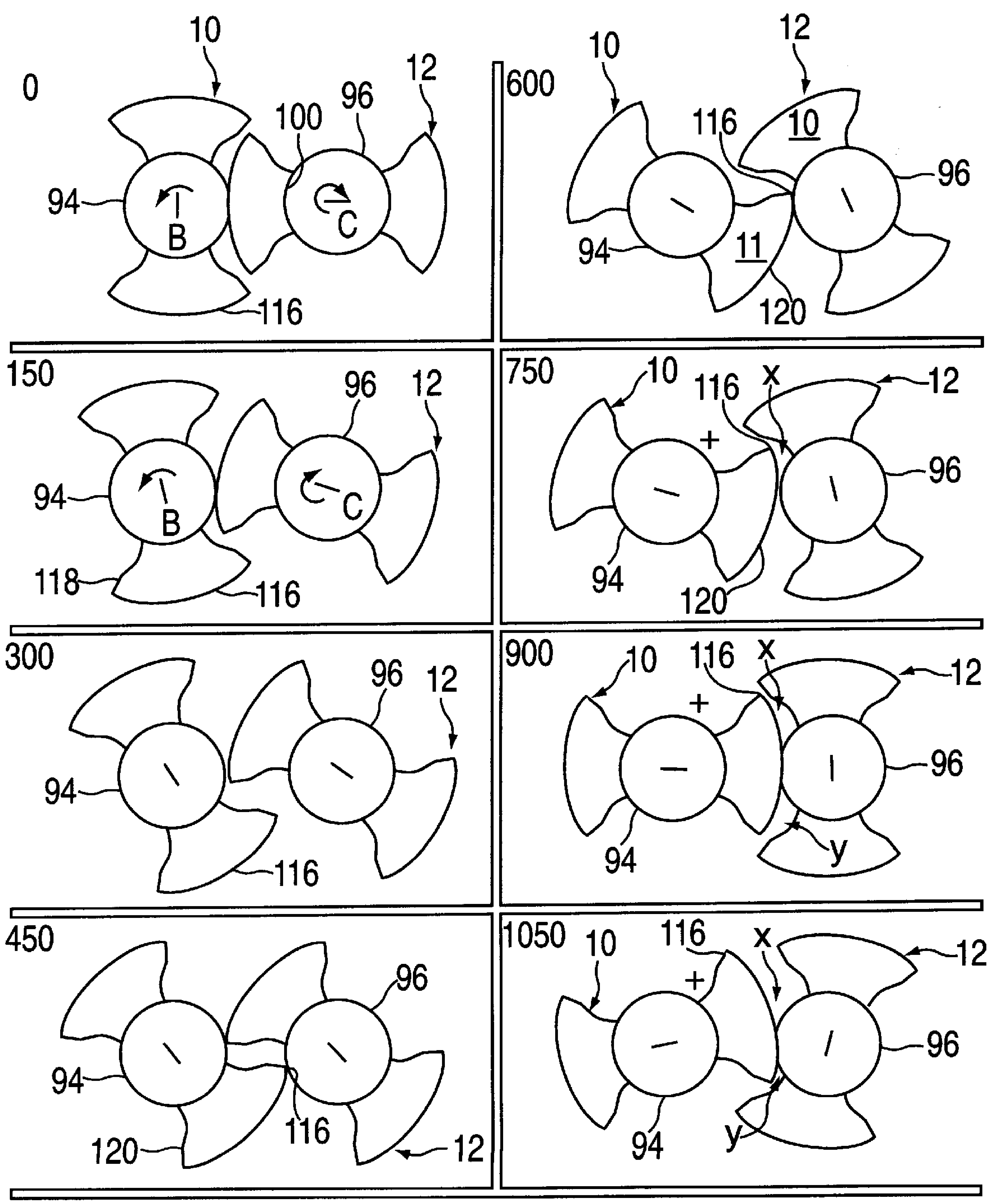



FIG. 9


0
10
12
100
96
94
B
C
116
600
10
12
116
10
96
94
11
120
150
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94
B
C
118
116
750
10
116
x
12
+
96
94
120
300
96
12
94
116
900
10
116
x
12
+
96
94
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450
96
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120
116
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1050
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116
x
12
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96
94
y

FIG. 11

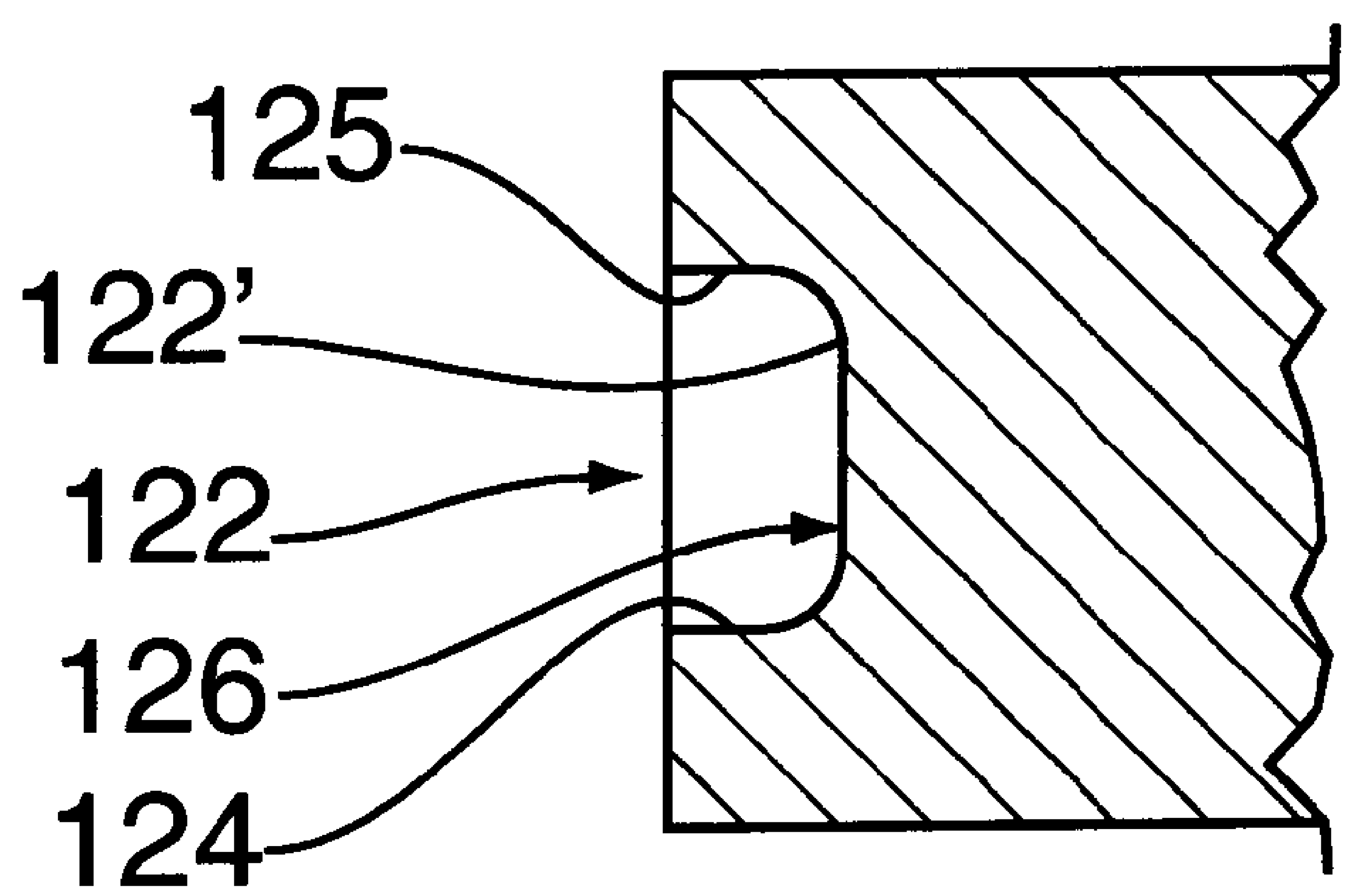


FIG. 12

# ROTOR FOR USE IN A ROTARY PUMP

## BACKGROUND OF THE INVENTION

This invention relates to a rotor for the use in a rotary pump and is particularly, but not exclusively, concerned with rotors for a rotary-piston/lobe pump

Fluid being pumped by rotary-piston/lobe pumps is prone to fluid cavitation particularly at the leading and trailing edges of the rotor. The problem of fluid cavitation is greatest at higher rotor rotation speeds.

## SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided at least one pump rotor mounted for rotation about a central axis comprising a continuous curved leading edge profile formed by at least one radius and/or a continuous curved trailing edge profile formed by at least one radius.

Preferably the leading edge profile is formed by a plurality of adjacent portions of radii. The trailing edge is preferably formed by a plurality of adjacent portions of radii.

The leading edge profile curve and the trailing edge profile curve are preferably formed by five adjacent portions of radii.

The radially outermost, relative to the rotor axis, radius portion is preferably the smallest in size relative to the other radius portions.

The radially innermost, relative to the rotor axis, radius portion is preferably the largest in size relative to the other radius portions. The size of the radii portions starting from the radially outermost radius to the radially innermost radius preferably ascends in size.

The continuous curve profile is preferably a sinuous cardoidal-like shape.

There is preferably provided a pair of inter-engaging rotors mounted for rotation about substantially parallel axes. The rotors are preferably mounted in a rotary-piston/lobe pump.

According to a second aspect of the present invention there is provided at least one pump rotor mounted for rotation about a central axis formed with at least one channel recess extending from the leading face of the rotor into the rotor and/or at least one channel recess extending from the trailing face of the rotor into the rotor.

The first channel recess is preferably disposed substantially radially below the leading edge of the leading face. The second channel recess is preferably disposed substantially radially below the trailing edge of the trailing face.

Each channel is preferably defined by two substantially parallel side portions extending perpendicularly from the surface of the respective leading and trailing faces and a channel base portion connecting the first side portion to the second side portion; the channel base portion being formed by a curve as viewed axially of the rotor. Preferably, as viewed axially of the rotor, the channel curve of the base portion comprises one concave radius portion and two convex radii portions disposed at opposite ends of the concave radius portion. The channel curve of the base portion is preferably formed with a substantially 'U' shaped cross-section.

Preferably the pump rotor comprises four channels, the arrangement being such that a channel is disposed in each of the two leading faces of the rotor and a channel is disposed in each of the trailing faces of the rotor, the channels being disposed equidistant from the axis of the rotor.



Preferably there is a pair of inter-engaging rotors mounted for rotation about substantially parallel axes.

The rotors are preferably mounted for use in a rotary-piston/lobe pump.

According to a third aspect of the present invention there is provided a pump rotor comprising a continuous curved leading edge profile and continuous curved trailing edge profile and at least one channel formed in the leading face of the rotor and a channel formed in the trailing face of the rotor, the arrangement being such that in use cavitation of a fluid worked on by the rotor is substantially prevented.

The rotor preferably rotates at speeds of up to 1400 rpm. It will be appreciated that the maximum speeds achievable depend upon the particular viscosity of the working fluid.

According to a fourth aspect of the present invention there is provided pump rotor removal means comprising at least one channel recess extending from the rotor face into the rotor.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, wherein:

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical section through a rotary pump assembly and shows the assembly of one of the piston/lobe rotors mounted on a drive shaft, the other piston/lobe rotor and associated shaft being omitted;

FIG. **2** is an exploded isometric view of the components of the pump assembly;

FIG. **3** is a isometric view of a rotor case portion;

FIG. **4** is an isometric view of a pump cover plate formed with spigot pillars;

FIG. **5** is a plan view of a rotor;

FIG. **6** is a cross-section of the rotor through A—A;

FIG. **7** is a front isometric view of the rotor showing a retaining nut;

FIG. **8** is a rear isometric view of the rotor;

FIG. **9** is a plan view of a curved leading edge profile of the rotor;

FIG. **10** is a plan view of a channel recess extending from the trailing face of the rotor;

FIG. **11** is a number of schematic views of the relative orientation of the contra-rotating rotors over a period of time; and

FIG. **12** is a cross section of the channel recess through B—B.

## DETAILED DESCRIPTION OF THE INVENTION

With reference to FIGS. **1** to **4** of the drawings, a rotary pump assembly **1** comprises a rotary pump **2** and pump mounting means **4**. The rotary pump **2** comprises a rotor containing assembly **6** and a gear containing assembly **8**.

The rotor containing assembly **6** comprises a pair of inter-engaging piston/lobe rotors **10, 12** mounted for contra-rotation within a rotor case portion **7** about substantially parallel axes **13, 14**; the rotor case portion is formed with an inlet port **9** and an outlet port **11** and comprises a circular cover plate **11**$^{1}$.

Substantially parallel shafts **15, 16** also mounted for rotation about the axes **13, 14** respectively , are connected to the respective rotors **10, 12**.

The rotors **10, 12** are secured on to the respective shafts **15, 16** by clamping/retaining nuts **17, 18**.

The shafts **15, 16** extend from the rotor containing assembly **6** along the axes **13, 14** through the mounting means **4** and into the gear containing assembly **8**.

Shaft **15** is a drive shaft and is driven by an electric motor (not shown) suitably attached at the shaft end $\mathbf{15^1}$. Prime movers other than electric motors may be used. It will be appreciated that by reversing the direction of the electric motor the direction of fluid flow through the pump containing assembly **6** will be reversed. Accordingly the port **9** will act as the fluid output port and the port **11** will act as the fluid inlet port.

The gear containing assembly **8** comprises a substantially circular chassis plate **20** formed with two circular ports **22, 24**; a chassis structure **26** suitably formed to house two sets of tapered roller bearing assemblies **28, 29** and carrying a pair of gears **30, 31** mounted on respective shafts **15, 16** for contra-rotation about the respective axes **13, 14**. The gear containing assembly **8** also comprises a cup-shaped enclosure **33** formed with an open end **34** and a port **35** through which the shaft end $\mathbf{15^1}$ extends, a lubricant filling port **37** formed through the uppermost region of the enclosure wall and a lubricant drain port **38** formed through the lowermost region of the enclosure wall (see FIG. **1**). The enclosure **33** is also formed with two substantially circular fluid level viewing ports **39**, $\mathbf{39^1}$ disposed generally facing each other and being in an orientation 90° from the ports **37, 38** respectively. It will be appreciated that when the orientation of the rotor containing assembly **6** and gear containing assembly **8** is changed from the vertical to the horizontal orientation the viewing ports **39**, $\mathbf{39^1}$ may be then used as either filling or draining ports and the inlet port **9** and outlet port **11** may be used as fluid level viewing ports. The material used to plug the four ports **37, 38, 29** and $\mathbf{39^1}$ has appropriate transparent properties.

The enclosure **33** is mounted upon an internal support structure **40** which is formed with a port **41** through which the shaft **15** extends. The enclosure **33** is not subjected to substantial stresses during the operation of the pump **1** and the primary function of the enclosure **33** is to contain lubrication fluid within the gear containment assembly **8**.

When the enclosure **33** is mounted on the support structure **40** the open end **34** abuts a sealing ring **36** which provides fluid sealing means between the enclosure **33** and the mounting means. Lubrication fluid is placed within the assembly **8** through the port **37** and provides lubrication means for the component parts within the enclosure **33**.

The mounting means **4** comprises a substantially vertical portion **42** comprising two substantially parallel flat mounting surfaces **44, 45** facing in opposite directions. From the lowermost region of the portion **42** there extends a pair of horizontal foot members **47**.

The portion **42** is formed with a circular through port **50** extending along axis **52** (see FIG. **1**). The portion **42** is also formed with a vertical slot **53** which extends through the portion **42** transverse to the axis **52**, so forming two substantially parallel vertical portions **43**, $\mathbf{43^1}$. The mounting surfaces **44, 45** are each formed with four threaded bolt holes which extend from the surfaces **44, 45** through the respective portions **43**, $\mathbf{43^1}$.

Disposed at the upper region of the portion **42** are two bridging portions **55, 56** extending from the outermost surface of the portion **42** into the slot **53**. (See FIG. **2**.)

The chassis structure **26** of the gear containing assembly **8** is formed with an annular rim $\mathbf{34^1}$ extending from the chassis structure **26** into the through port **50** of the mounting mean **4**. The radially outermost surface of the annular rim $\mathbf{34^1}$ is in sliding contact with the radially innermost surface of the portion **42**.

Referring to FIG. **3**, the rotor case portion **7** is formed with a generally oval shaped rotor recess **58** adapted to house the lobe rotors **10, 12**. Two substantially circular through hub bore ports **60, 62** extend from the rotor recess **58** coaxially along respective axes **13, 14** and are formed so as to receive seal assemblies **64, 66** disposed on respective shafts **15, 16**.

The inlet port **9** and outlet port **11** extend into the rotor bore **58** from opposing directions. At the innermost part of the inlet port **9** and outlet port **11** there are formed curved scallops **68, 69**.

The rotor case portion **7** is attached to the mounting surface **44** of the mounting means **4** by means of rotor case threaded bolts **70**.

The rotor case portion **7** is formed with an annular rim **71** extending from the case portion **7** into the through port **50** of the vertical portion **43**. The radially outermost surface of the annular rim **71** is in sliding contact with the radially innermost surface of the vertical portion **43**.

The rotor case portion **7** comprises a flat surface **80** substantially perpendicular to the axes **13, 14**. Extending from the mounting surface **80** and through the rotor case portion **7** there are eight threaded bolt holes **82**.

Referring to FIG. **4**, the cover plate $\mathbf{11^1}$ is formed with bolt holes **84** extending therethrough and arranged so that they align with the respective holes **82** in the rotor case portion **7**. Extending from a flat mounting surface **90** into the cover plate $\mathbf{11^1}$ there are four recesses **92** formed to receive the bolt heads of the rotor case bolts **70**. The cover plate $\mathbf{11^1}$ is also formed with a generally oval shaped channel recess **95** extending from the mounting surface **90** into the cover plate **11**. The recess **95** is disposed radially within the recesses **92** and the holes **84**. The cover plate $\mathbf{11^1}$ comprises two stationary substantially circular spigots **94, 96** each formed with a recess **98** provided to receive the retaining nuts **17, 18**. The outermost wall of each of the spigots **94, 96** is formed with curved scallop **100** formed to allow the rotation of the rotors **12, 10**.

When the cover plate is bolted to the rotor case **7** an oval seal ring **102** is located within the oval recess **94** and provides sealing means between the mounting surfaces **80** and **90**, so containing fluid being pumped from the inlet port **9** through the recess **58** and out through the outlet port **11**.

When the rotary pump assembly **1** is in a substantially disassembled state the orientation of the rotor containing assembly **6** and the gear containing assembly **8** can be rotated by angular intervals of 90° apart, relative to the pump mounting means about the central axis **52** and subsequently reassembled.

It will be appreciated that the orientation of the gear containing assembly **8** and the rotor containing assembly **6** about the axis **52** depends upon the orientation of the fixing holes **51** about the central axis **52**. The rotation of the rotor containing portion and the gear containing portion relative to the mounting frame is substantially prevented by means of at least one dowel-like protrusion (not shown) extending from the respective mounting faces of the rotor containing portion and the gear containing portion; the protrusions being engaged, in use, in corresponding recesses (not shown) formed in the respective mounting surfaces of the mounting frame. The four holes **51** can be disposed in any required rotation about the axis **52** from the vertical plane such that the gear containing assembly **6** and rotor containing assembly are disposed in the required orientation about the axis **52**.

The features of one of the rotors will now be described, however the rotors **10, 11** are substantially the same shape formed and with essentially identical features.

Referring to FIGS. **5** to **10**, the rotor **10** comprises a generally cylindrical rotor hub portion **108** formed with two piston wing portions **110, 111**. The piston wing portions **110, 111** are disposed transversely of the axis **13** on a substantially flat surface **112** of the hub portion **108**. Extending from the surface **112** coaxially with axis **13**, and disposed radially within the rotor hub portion **108**, is a tubular portion **114** through which the end of shaft **15** passes when the rotary pump assembly is in an assembled state.

Each piston wing portion **110, 111** is formed with a sinuous curved leading face region **113** and a sinuous curved trailing face region **115**.

The radially outermost (relative to the rotor axis) region of the leading face region **113** is formed with a leading curved edge part **116** and the radially outermost region of the trailing face region is formed with a trailing curved edge part **118**.

Referring to FIG. **9**, the respective leading and trailing curved edge parts **116** and **118** each comprise a smoothly continuous convex curved profile formed by adjacent portions of radii R1, R2, R3, R4 and R5. The said radii ascend in size, from R1 being the smallest in value to R5 being the largest in value.

Disposed radially below (relative to the rotor axis) each of the curved edge parts **116, 118** is a smoothly continuous concave curved profile formed by adjacent portions of radii R6 and R7. The radius R6 is of a greater size than the radius R5. The radius R7 is of a lesser size than R6. Disposed radially below the radius R7 is a concave portion formed by radius R8.

Typical values for the radii are as follows:

R1=1.29

R2=2.8

R3=4.43

R4=6.75

R5=13.42

R6 32 21.97

R7=13.35

R8=0.5

The respective radially outermost surfaces **120, 121** of the piston wing portions **110, 111** extend between the leading edge region **116** and the trailing edge region **118** of the wing portion **110, 111** respectively. In use the rotor **10** rotates about axis **13** in direction B. The rotor **11** rotates about axis **14** in direction C (see FIG. **11**).

The angle between the two lines where the outermost surfaces **120, 121** meet the respective curved leading edge and curved trailing edge is called the outer landangle $\alpha$.

Each curved leading face region **113** and each curved trailing face region **115** are respectively formed with channel recesses **122**. Each channel recess **122** is defined by two substantially parallel sides **124, 125** extending perpendicularly from the surface of the face regions into the respective piston wing portions **110, 111** and a curved channel base **126** extends between the parallel sides **124, 125**. The curved channel base **126** is formed with a substantially 'U' shaped transverse cross-section $122^1$ (See FIG. **12**).

With reference to FIG. **10**, the base **126**, as viewed axially of the rotor, is formed by a concave radius portion R9 and two convex radius portions R10, R11 disposed at opposite ends of the radius portion R9. The radius R9 is of greater size than both the radii R10 and R11.



Typical values for the radii are as follows:

R9=13.82

R10=2.0

R11=0.5

Referring to FIG. **11** the contra-rotating rotors **10, 12** rotate in directions B, C and have a 90° offset with respect to each other's orientation. As the two rotors **10, 12** rotate the leading edge part **116** of rotor **10** approaches the stationary circular spigot **96** as shown in frame **450**. With the continuing rotation of the two rotors the outermost surface **120** of the rotor **10** passes closely by the scallop **100** and an increasing volume X is created between the rotors **10, 12** (see frames **750, 900** and **1050**). FIG. **11** does not show the detail of the curved rotor and the rotors shown in FIG. **11** are only pictorial representations.

During the particular orientation previously described, fluid entering the rotor case **7** via the inlet port **9** will flow into the increasing volume X as the rotors **10, 12** rotate. The passage of the fluid flow into the volume X is aided by the curved trailing face region **115** and the curved leading face **113** of the wing portions **110, 111**. Of particular importance is the curved edge parts **116, 118**.

The passage of the fluid flow into the volume X is also aided by the channel recesses **122**.

The fluid flow is aided to such an extent that fluid cavitation is substantially reduced and ideally prevented. Due to the curved face regions of the rotor and the channel recesses the rotors are able to rotate up to speeds of 900 to 1400 rpm without any substantial fluid cavitation.

The curved surfaces of the rotors and the channel recess also aid the fluid flow out of the decreasing volume Y.

It will be appreciated that the Channel recesses **112** in the leading faces **113** and trailing faces **118** of each of the rotors **10, 12** provide an increased volume which will be filled by fluid as the respective rotors rotate.

The above described features will help reduce unwanted noise which is generated when fluid cavitation occurs.

It will be noted that the channel recesses **112** may also be used to remove the rotors **10, 12** from the shafts **15, 16** during disassembly of the rotary pump assembly.

An appropriate tool is placed within the recesses **112** and the rotors **10, 12** withdrawn from the shafts **15, 16**. The recesses **112** may also be used during the assembly of the rotary pump assembly.

What is claimed is:

**1**. A pump including first and second rotors, the first rotor forming first piston wing portions and the second rotor forming second piston wing portions, the first and second piston wing portions rotating during operation of the pump without meshing with one another, the first rotor being mounted for rotation about a central first rotor axis and comprising at least one continuous curved edge profile wherein the at least one continuous curved edge profile is one of a continuous curved leading edge profile formed by at least one radius and a continuous curved trailing edge profile formed by at least one radius.

**2**. A pump rotor as claimed in claim **1** wherein the leading edge profile is formed by a plurality of adjacent portions of radii.

**3**. A pump as claimed in claim **2** wherein the leading edge profile curve and the trailing edge profile curve are formed by five adjacent portions of radii.

**4**. A pump as claimed in claim **2** wherein relative to the rotor axis, the radially outermost radius portion is the smallest in size relative to the other radius portions.

**5**. A pump as claimed in claim **2** wherein relative to the rotor axis, the radially innermost, radius portion is the largest in size relative to the other radius portions.

6. A pump as claimed in claim **2** wherein the size of the radii portions starting from the radially outermost radius to the radially innermost radius ascends in size.

7. A pump as claimed in claim **1** wherein the trailing edge profile is formed by a plurality of adjacent portions of radii.

8. A pump as claimed in claim **1** wherein the at least one continuous curved profile is a sinuous cardoidal-like shape.

9. A pump as claimed in claim **1** wherein the second rotor is mounted for rotation about a second rotor axis substantially parallel to the first rotor axis for interengaging rotation with the first rotor.

10. A pump as claimed in claim **9** wherein the pump is a rotary-piston/lobe pump.

11. A pump as claimed in claim **1** wherein the first rotor rotates at speeds up to 1400 rpm.

12. A pump as claimed in claim **1** wherein the first rotor defines a radially outermost surface extending along a portion of a circle centered about the first rotor axis and wherein the radially outermost surface is coupled to at least one of the leading edge and the trailing edge of the first rotor by the continuous curved edge profile.

13. A pump including first and second rotors, the first rotor forming first piston wing portions and the second rotor forming second piston wing portions, the first and second piston wing portions rotating during operation of the pump without meshing with one another, the first rotor being mounted for rotation about a first central axis and comprising one of a first channel recess extending into the first rotor from a leading face of the first rotor and a second channel recess extending into the first rotor from a trailing face of the first rotor.

14. A pump as claimed in claim **13** wherein the first channel recess is disposed substantially radially below a leading edge of the leading face.

15. A pump as claimed in claim **13** wherein the second channel recess is disposed substantially radially below a trailing edge of the trailing face.

16. A pump as claimed in claim **15** wherein the channel curve of the base portion as viewed axially of the first rotor comprises one concave radius portion and two convex radii portions disposed at opposite ends of the concave radius portion.



17. A pump as claimed in claim **13** wherein each of the first and second channel recesses is defined by first and second substantially parallel side portions extending perpendicularly from a surface of the respective one of the leading and trailing faces and a channel base portion connecting the first side portion to the second side portion.

18. A pump as claimed in claim **17** wherein the channel base portion is formed by a curve as viewed axially of the rotor.

19. A pump as claimed in claim **17** wherein the channel curve of the base portion is formed with a substantially 'U' shaped cross-section.

20. A pump as claimed in claim **13** wherein the first rotor comprises four channels, the arrangement being such that a channel is disposed in each of the two leading faces of the first rotor and a channel is disposed in each of the trailing faces of the first rotor, the channels being disposed equidistant from the first axis.

21. A pump as claimed in claim **13** wherein the second rotor is mounted for rotation about a second axis substantially parallel to the first axis and wherein the first and second rotors interengagingly rotate about the first and second axes.

22. A pump as claimed in claim **21**, wherein pump is a rotary-piston/lobe pump.

23. A pump including first and second rotors, the first rotor forming first piston wing portions and the second rotor forming second piston wing portions, the first and second wing portions rotating during operation of the pump without meshing with one another, the first rotor comprising a continuous curved leading edge profile and having at least one channel formed in a leading face thereof and a channel formed in a trailing face thereof such that, in uses cavitation of a fluid worked on by the first rotor is substantially prevented.

24. Pump rotor removal means comprising at least one channel recess extending from the rotor face into the rotor.

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